multiplied by no other change than the addition of more water (steam) from the boiler.

The phenomena and effects of combustion above cited seem to justify the following statement of theory:

The Holland locomotive retorts liberate a pure hydrogen fuel from the mutual decomposition of certain proportions of naptha and steam. The regular temperature of the furnace keeps the retorts hot enough to disengage the oxygen of steam in the presence of the carbon of naptha, the chemical attraction of these two elements causing them to unite in the proportions of full combustion, and to form carbonic acid within the retorts. The released hydrogen is the only combustible ingredient left to issue at the burners. All the heat of both of these combustions—that of the carbon within the retorts and that of the hydrogen at the burners—is conserved and utilized in the same furnace for the making of steam.

The question now arises on the true causes of the enormous excess of calorific power developed by a given amount of fuel through the water gas process, as compared with the results of direct combustion of the same fuel. Assuming that the amount of carbon entering the retort takes oxygen from the steam with which it mingles, to the proportion of full combustion, and thus liberates just sufficient hydrogen to re-engage the same amount of oxygen; we have first to inquire what proportion exists between the amounts of heat generated by the union of that or any given quantity of oxygen with its proper complements of carbon and of hydrogen respectively. A number of authorities have determined this question experimentally, with results not widely different. According to Grassi, the number of pounds of water raised one degree by the union of one pound of oxygen with its full combining equivalents of carbon and hydrogen, respectively were 2,893 and 4,333. The direct gain by exchange, therefore, would be almost exactly fifty per cent. Numerous experiments by Bunsen and Fyfe are also said to have proved (in indirect accordance with those above referred to) that the fuel (hydrogen) obtained by the decomposition of water, yields a considerable excess of heat above that absorbed in producing the decomposition.

We have made a close scrutiny of the Holland apparatus and its operation for domestic purposes, as exhibited in this city, at the offices of the Heat, Light and Power Company, No. 18 Vesey street. An even pressure of both water and naphtha is secured by an elevated tank for each purpose, at the top of the room. The pipes running from these tanks to the cooking-stove and range are laid in full view, and strict tracing and examination of their course and connections at every point showed that there was no other possible source of supply, of any kind, for the retorts and burners, The oil tank measured 25⅞ inches in diameter, and was computed to hold nearly 2.22 gallons to the inch in depth. In running the cooking-stove, with the oven constantly at a sharp baking heat, the oil was lowered only $\frac{1}{16}$ inch in half an hour, or about one quart (¾ cent) an hour. The whole interior of the store, which had been used a year last May, was free, not only from ashes and soot, but from discoloration, which, obviously, much assisted the effectiveness of the fire, as compared with the coating of non-conducting material accumulated in using crude fuel. It was found impossible to obtain a trace of smoke or odor from the flame upon a white handkerchief; so that, of course, the usual free carbon, hydro-carbon, carbonic oxide, and other gases of crude fuel, could affect neither the atmosphere nor the flavor of food cooked in direct contact with the flame. In the large cooking-range, a third pipe is introduced for the distillation of illuminating gas, simultaneously with the ordinary use of the range. The adjustment and operation excited much admiration. In the progress of the oil through successive coils of this pipe, within the fire box, the several hydrocarbon mixtures it contains are converted, by successive gradations of heat, into a single homogeneous and fixed gas, which resists the most extreme cold of our climate, without condensation, and runs free from sulphurous and other impurities, requiring only dilution with air. After burning a scant $\frac{1}{16}$ inch of oil, the time being taken, the gas-making pipe was opened by simply turning a cock, and in exactly one half the time enough gas was made and measured to amount to 12.55 cubic feet, if diluted to twelve-candle power; when the total oil out was found to be exactly $\frac{3}{32}$ inch, showing a barely perceptible difference from the rate of consumption without making gas, but too fine to measure with the instruments at hand. Roughly allowing it to be $\frac{1}{64}$ for the gasmaking, the cost of the 12.55 feet would be .0347 gal., or about 2¾ gal. per 1,000 feet. This is ¼ gal. in excess of more exact measurement previously taken by gas experts.

But the rough experiment with the locomotive evidences a gain of fully one thousand per cent, from the exchange of carbon for hydrogen, estimating the fuels by cost, in a practical way; although the liquid fuel is of course the dearer of the two, and the gain over the intrinsic value of the exchanged carbon, if it could be ascertained, would therefore be still greater. Fifty per cent from the exchange, then, is at best but five per cent of the total gain, and the remaining 95 per cent must be otherwise accounted for. Nor is there any lack of good reasons for even this enormous difference. In the first place, the carbon is consumed in pure oxygen from steam, no atmospheric air having access to it in the retorts, and therefore the large absorption of heat by the nitrogen of the air that feeds the coal fire, is wholly saved in the water gas process. The consumption is also perfect both of the direct and the produced fuel, against a semi-consumption in the coal furnace. Thirdly, the combustion of the carbon, with all its heat antecedent and consequent, is closely confined in the retorts, from which the heat can escape only by radiation into the boiler, with the exception of the very restricted vent of the hot gases through the burners. Fourthly, the hydrogen obtained issues from the burners at a very high prior temperature, whereas the coal enters the furnace cold. Finally, the hydrogen flame is a vastly more advantageous heating agent than any form of crude fuel, from its unequalled intensity and rapidity of action, and also from its direct contact with the iron, as against the slower processes of radiation and conduction employed by the coal in the furnace. The rapidity with which heat is imparted increases in a geometrical ratio to the increase of it sintensity, and since the hydrogen flame is many times hotter than incandescent carbon, this concentrated heat must have a vastly greater effect, unit for unit, in any given time of passage through the flues. Considering that 90 per cent of direct waste is a moderate allowance in the ordinary firing of a locomotive, it would seem on the whole that we are justified in expecting yet greater economy from this process rather than in theoretically distrusting the results so far reported.

PROGRESS IN MIXED METALLURGY.

By William C. Conant.

Of the fundamental mechanic arts substantially developed before Science or History had a name, Metallurgy was the beginning and the common parent. 'When Adam was yet in middle life, the genius of Tubal-Cain divined and explored the capabilities of the workman's metals, copper, tin, zinc, and iron; fused and mingled them, wrought from them the tools of every craft, and became "the instructor of every artificer in brass and iron." It were hopeless, therefore, to question subsequent records of Time for the era or the occasion of any of the more essential developments in this art of arts. So far as the native surface metals are concerned, it is probable that all the more important metallurgical processes were understood, for substance, long before the flood. Copper and tin, the principal ingredients of bronze, being found comparatively pure at the surface, were naturally the earliest

metals combined and used for mechanical and military purposes. The same precedence of these metals continued, locally at least, and, so far as can be discovered, down to historic times. The Roman historians record it. Weapons, armor, and tools of bronze, hard enough for cutting granite, abound among the remains of primitive antiquity, and have given to that vague epoch the title of the age of bronze: the so-called stone age being of no particular order in time, but rather the universal age of savageism, from the earliest vagrants of the human race down to the recent aborigines, so-called, of our own country.

The disposition to try what will come of mixing materials may be assumed as a prominent native factor of invention in all ages, and as especially prominent in the infancy of knowledge, when every material and every property of materials was a mystery only to be experimented on. Nay, the bare factor of accident would be sufficient to insure the mixture of various metals, ores and earths in the very first experiments. Copper and tin coming out first, as bronze, at once stimulated and assisted an eager search for further discoveries. They built the furnaces and quarried the fuel that ultimately brought to light the treasure concealed in dull brown rocks of iron ore. The more facile ore of zinc (in the presence of copper) if accidentally at hand, would enter earlier, or, possibly, earliest, into the kaleidoscopic series of the smelter's products, with the most exciting brilliancy of effect; promising coveted gold without limit, and preparing, perhaps, the first sad catastrophe of inventive expectation unrecorded in any patent office or prospectus of incorporation. Down almost to the 19th century (1781) brass was made by mixing the zinc ore directly with copper; and down to the 16th century this had been done, from the earliest times, without a suspicion that the magical stone was anything but one out of hundreds of like mysterious minerals, among which a potent and supreme "philosopher's stone" might yet be found. No wonder that infinite possibilities of metallic splendor and preciousness stretched out before the imaginations of the alchemists in the vast field of unexplored mineral combinations before zinc was discovered as a metal and the nature and scope of the alloys were defined.

To these limitations, however, modern philosophy and discovery have given a new and again undefinable extension. They have not revived alchemy, but they have revived a more trustworthy probability, and a more philosophical pursuit of radical improvement in the character of the alloys. In general it may now be stated that the labors of new experimenters with the new lights and resources already promise to popularize little less than the beauty and incorruptibility of the precious metals in the equipage of common life and arts, and in combination with some of the qualities hitherto inseparable from a coarse, dull and corruptible texture, as in iron.

The discovery of nickel and German silver were marked steps in the direction of the new era, yet failed to approximate it; as we see in the fact that nickel has proved hitherto but a material, and German silver a basis, for the temporary and unsatisfactory varnish of beauty called plating. Nickel was found too refractory a metal to be worked solid for purposes of general utility or even of ornament. Qualified by other metals, as in German silver, the same refractory temper still rendered it impracticable, except in proportions too small to impart its clear color and splendor, with its clean, resistant texture and temperature, to the composition formed. Every workable substitute for silver betrayed, more or less, a constitutional sickliness, of jaundiced tint, sweaty feel, and corrupt odor. No actual progress was possible until the discovery that the refractory quality of nickel was due to its absorption, when in a molten state, of certain gases which might be chemically removed. This discovery was made and published in Germany, two or three years ago, with the magnesium method of purifying and reducing the metal to malleability. In practical results, however, we know of little to report as yet from the other side of the Atlantic; whether it be on account of expensiveness in the process, or inability to form alloys of this in itself too expensive metal that are satisfactory at once in cost and in qualities. One suggestion of possibly great importance comes from the German nickel manufacturers, in the comparison of the purified metal with Bessemer steel, with which it is represented to be almost identical in practical properties; raising even a suspicion in some minds whether the two may not be modifications of one metal, or of some protean metallic element, of unconjectured range. The whole range of metals, indeed, would not be more extreme, nor, perhaps, more difficult of practical reconstruction than that of carbon. The speculations and partial successes of Mr. Lockyer in the direction of a theory of unity, or rather of duality, and convertibility, in matter, are here forcibly recalled to mind; suggesting that all its families may be the progeny of two universal parent substances, such as hydrogen and oxygen. What if the truth of Nature, after all, lay, metaphorically, near to the surface and to the mystical vision of the old childlike sages, who saw in the "elements" all-generative powers, as Science finds in one of them (fire) a form, and as represented in the Sun the prime form perhaps, of all organic energy? What if Science should yet discover that the alchemists themselves had a true, if not practicable, end in view? Man's dominion in Nature is too marvellous in its present beginnings, for anything to be incredible as to its future perfection.

On the American side the modern philosopher's stone has beensought of late years, with sanguine ardor. A number of different fortunes of respectable size have been sunk in the melting-caldrons, out of which have arisen a succession of bright apparitions, only to prove intractable for use, or turn the old inevitable sickly cast after brief shining. None of our practical experimenters, so far as I am aware, have struck the true lead, the purification of nickel, with one exception. No other man of our day, probably, has given so many years of metallurgical labor so hard and practical, together with study so profound, to the assimilation of the necessary alloys for gold and silver, to the appearance and properties of those metals, as Mr. Charles Wessell of New York. What our chemists may have accomplished, or seemed to accomplish, with a few ounces of metal in the laboratory, it is of less importance to inquire than would be generally supposed. Such achievements, whatever they might be, would have no necessary value, or even validity, in practice: none possible, indeed, unless there were given with them a practical metal-mixer uniting scientific genius and research with the technical knack and stalwart physical capacity for handling metals by the ton in the furnace, to the purpose for which he intends them. Mr. Wessell, indeed, meets this description; but it would be needless to tell any manufacturer of brass or German silver, that no other known counterpart exists. The men they depend on for this service work solely by blind knack, which they catch and lose alternately in the most unaccountable manner, contributing a material percentage to the market cost of these common compositions by their own inevitable percentage of uncertainty, failure, and destruction of materials.

Charles Wessell, the metallurgist of the Holmes & Wessell Metal Company of New York, came to this city from Rome, in this State, a modest working man, whom the future famous discoverer of a genuine popular rival to the precious metals must make haste to head off, if indeed it be not already too late. It is thirteen years since Mr. Wessell began his metallurgical experiments and inventions, by undertaking successfully to electro-deposit a combination of three metals which most chemists would even now pronounce it impossible to hold together under the battery. A very distinguished chemist to whom the product was submitted, gave this assurance in absolute

terms, before making his analysis. His own analysis confounded him; he frankly certified the three metals found in the deposit; and in his subsequent lectures has referred very pointedly to undiscovered possibilities in the philosophy of metals. Undiscovered—for it is the good fortune of the solitary discoverer that the mediating agent vanishes in his thaumaturgic-metallurgic act into thin air, leaving no clue by which the scientific detective can shadow him as yet. Hence it is impossible for the metal worker, or even the chemist as yet, to recast certain of the Wessell metals; since it is too much to ask of him to give away the "combination" that locks his own hard-earned reward against the rapacity of mankind. Science itself must be content for the present with the accomplished facts shown, and with what their author can afford to disclose of methods and principles. Thus, it has become possible to give the necessary alloy to silver and gold with more suitable ingredients than could be used heretofore; ingredients which but imperceptibly deteriorate either the color or the incorruptibility of the precious metals, and, so far as silver is concerned, effect even a remarkable improvement. Stranger results have followed and are still progressively following, from the same discovery, in building up towards gold and silver from the basis of alloys. All of Mr. Wessell's novel compositions—already sufficient to constitute an era in the history of the art—have their origin and their constant method of development in that stroke of genius; for I know not what else to call it in view of the systematic unfoldings and correlations of it in the hands of the same master. The depositing battery, instead of the crucible, is the instrument by which the practicability and the effect of every combination conceived by him is tested in the first instance. As a consequence, partly of this scientific certainty in method, partly of practiced genius in adjusting heat and other delicate conditions according to bulk, weather, color, radiance, fumes, and the hundred unspoken mysteries of his art, Mr. Wessell's matured mixtures, from common brass and German silver upward, come out uniformly and infallibly what they are intended to be; astonishing to veteran manufacturers of metals who have associated him with them in their affairs, and a fact which I hazard little in opining to be without precedent in mixed metallurgy.

In the course of his novel processes of research, Mr. Wessell discovered, probably first, or at least long before it was promulgated elsewhere, the secret of making nickel pure and malleable, and not only so, but also of keeping it pure and malleable, throughout all combinations, processes and proportions, in which he chooses to introduce it. Magnesium was first or independently tried by him; but discarded for a more practical and economical agency, incidentally discovered in experimenting on qualifying or auxiliary mineral ingredients. The means also by which it turns out that the gases so fatal to nickel are kept out after being once eliminated, were a part of the general precautions of an extremely vigilant and, as it were, sensitive operator, rather than preconceived expedients for that express purpose. The methods and results are no worse, perhaps all the better, that their theory was learned from them, rather than they from the theory. It became a significant observation to Mr. Wessell, that various metals, malleable in the original smelter's ingot, grow unmalleable by remeltings. He reasoned that in the large smelting furnaces, from which the metal is drawn off at the bottom, the most of the mass is secluded from unfriendly influences, whatever these may be, until it is suddenly poured into close moulds and cooled: whereas, in the small open furnace or crucible of the foundry, the metal is poured off from a freely exposed surface; suggesting that to his own closely-covered processes was due the continued freedom of the metal from the refractory temper once extracted.

With the chronic intractability of the superior metal has been removed the hitherto insurmountable obstacle to its introduction in sufficient force to impart its noble qualities to a workable composition. It can now be used in any percentage necessary, and the Wessell process for malleability, unlike the German, is one that adds no extra expense. Its remarkable lustre and beauty of color are now as familiar as those of silver, through extensive use in electro-plating, and are rapidly approaching equal favor in the public taste. What is not so familiar to most minds, is the palpable superiority of nickel, at all points, for fine utensil service, such as we require of spoons, forks, knives, &c., for the table. Color is a matter of taste; but there is no disputing the superior durability of lustre and polish as well as of form, that belongs to the harder metal. It yields only to gold in point of resistance to oxidation and corrosion, and defies the attacks of organic acids, sulphur, &c., that instantly mar the beauty and cleanliness of the best silver. Still less commonly understood is the force of character, so to speak, with which this metal suppresses the meaner colors and weaker susceptibilities of lower metals united with it, by its own noble qualities, even when the odds in quantity are largely against it. To this we already owe solid Wessell-silver table ware, not noticeably inferior in any respect to pure nickel, yet at no greater cost than the perishable sham of plated goods. Manufacturers of the latter may not look with favor on the substitution of goods that would last four generations for goods that must be renewed four times in a generation. But such a revolution as this comes of its own weight and carries all before it. The present vast production of plated ware must in a few years become a mere reminiscence, in all its numerous departments.

To an important class of readers and interests, the bearing of Mr. Wessell's discoveries on the metallurgy of gold and silver will seem most worthy of attention. Alloys are necessary to these metals, both for mechanical and commercial reasons. It is no longer necessary, however, to impair their properties or appearance in making them workable or saleable. All grades of gold treated with the Wessell alloys are of uniform color and lustre with eighteen-karat gold, and require more than usually severe and expert testing to detect any differences whatever, between them. By way of illustration, it may be stated that the alloying compositions themselves do not oxydize perceptibly when exposed to the action of the atmosphere in cooling from the molten state, nor yet in the process of granulation. Manufacturing jewellers pronounce the alloy for gold in all respects equal to eight-karat gold itself, although there is not a particle of gold in it. The alloy for silver is a specially important improvement in the non-tarnishing quality. This may be illustrated by an incident in the experience of a leading manufacturer of sterling silver ware—the celebrated Whiting Manufacturing Company. A quantity of sterling had been made up with Wessell alloy, according to standard, 925-1000ths fine. Of the goods manufactured from this lot, a few were wrapped up with others of the same standard (uniform in all the goods of these manufacturers) but made with the usual copper alloy. After lying some twelve months forgotten and undisturbed, the parcel was met with in taking account of stock and opened. The regularly alloyed metal was found coated with the inevitable black oxide, while the original brilliancy of the Wessell-alloyed metal had barely acquired a warm tint. The writer is indebted for this information to one of the chief managers of the Whiting Manufacturing Company. The alloyed silver, electro-deposited on a spoon by Mr. Wessell, was declared pure by the testing chemist of one of our large plating establishments, who hotly called the metallurgist a fool to his face for insisting that it was or could be otherwise. Being requested to expose the spoon to the action of sulphuretted hydrogen in company with another of chemically pure electro-plate, the chemist was non-plussed by finding that while, of course, the latter was instantly blackened, the

color and brilliancy of the Wessell-alloyed silver remained unaffected. The same peculiarity has been observed by the writer personally in Mr. Wessell's low-priced nickeline metal, which holds a pure and strong lustre throughout indefinite exposure to every test that befalls (and befouls) a silver spoon in domestic use.

"INTEGRAL LUBRICATION."

Integral lubrication is an expression that has been selected to describe the effect of a lubricating element which is itself an *integral part* of the surfaces in contact and relative motion, as distinguished from a foreign or extraneous lubricant introduced between the surfaces, requiring constant renewal, and subject to displacement, consumption, waste, deterioration by heating, &c., and to various other imperfections and inconveniences.

Friction results from the resistance of particles in contact to change of position. Lubrication consists in their non-resistance to change of position, as in fluids. Within themselves, therefore, fluids have the property of integral lubrication. Interposed between solid surfaces, whose fixed particles resist change of position, fluids serve to separate such surfaces by a stratum of non-resistant or mobile particles, and thus supply *extraneous* lubrication.

The idea of establishing the lubricating, non-resistant or mobile element integrally in the bearings themselves, rather than extraneously as a distinct intermediate stratum, was the conception of Dr. Stuart Gwynn, the noted engineer and inventor, of two generations, to whom we owe the Gwynn pump and numerous other long established appliances. This idea is the basis of more than twenty patents, relating to the series of compositions by which it is realized under different conditions, all known under the common designation of METALINE.

The conception of union between the opposite properties of solidity and non-resistance, and of integrity and distinctness, in one metallic body, certainly had the boldness, as its realization showed the power, of a stroke of genius.

The important point to be reached by Dr. Gwynn, after his discovery of the possibility of "Integral Lubrication," to render it of practical value, was to make exact determinations of the effect produced on metals, their alloys, oxides, etc. by enormous pressure when they are put into hardened steel moulds of great strength. These trials extended over several years of time and under pressures from five tons or 666⅔ atmospheres to one hundred tons or 13,333⅓ atmospheres per square inch. In these trials he found, without doubt, the true law of the "*Flow of Solids.*" His determinations were finished in 1860.

This department of physics has, since then, been extensively worked by other scientists, and many of the results arrived at have been published. One of the latest of these contributions is an interesting memoir published in 1881 in the "*Revue Scientifique*," by Mr. W. Spring, a German chemist, from which we abstract as follows:

> The substances experimented with were taken in the form of fine powder, and subjected, in a steel mould, to pressures varying from 2000 to 7000 atmospheres per square centimeter. Lead filings under a pressure of 2000 atmospheres were transformed into a solid block which no longer showed the least grain under the microscope, and the density of which was 11.5, while that of ordinary lead is 11.3 only. Under 5000 atmospheres the lead became fluid and ran out through the interstices of the apparatus. Toward 6000 atmospheres, zinc and tin appeared to liquefy. Powders of zinc and bismuth at 5000 to 6000 became solid blocks of a *crystalline* fracture. Powders of soft and of prismatic sulphur were transformed into solid blocks of octahedric sulphur. Red phosphorus appeared to pass into the denser state of black phosphorus. Binoxide of manganese and the sulphides of zinc and lead in powder, *weld* when compressed, and exhibit the appearance, respectively, of natural crystallized pyrosulite, blende, and galena. A number of pulverized salts solidify through pressure and become transparent, thus proving the union of the molecules.

The common property in Metaline and the natural lubricants (fluids) is, of course, mobility or non-resistance to change of position in the particles. This property or effect, results, again, from exceeding minuteness, hardness, roundness and polish of particles; obtained in the artificial instance, by pulverization, attrition, and extreme sifting of metallic particles. It is obvious that the particles of soft or brittle substances, such as flour of wheat or dust of stone, are not capable of the rounding polish and consequent slipperiness (integral lubrication) of metallic particles; nor yet of a kindly interpenetration with the surface particles of solid metal. Hardness, also, or resistance to change of form, coupled with non-resistance to change of position, may be an essential requisite to fluidity; so that possibly the particles of water or oil may be much harder as well as finer than those even of metals. The metals, however, are generally susceptible of a degree of polished and rounded comminution that yields a very slippery product. The fluid-like mobility of small shot is a rough illustration of this condition.

The next stage of the invention is to penetrate and incorporate the solid bearing surfaces with the non-resistant or mobile particles. This is effected by two operations, one the product and complement of the other. The prepared particles are in effect compressed into frequent sockets in the bearing surface, so as in the first place to occupy directly the larger part of its area, and in the second place to allow the outer particles (slightly raised) to attach to the microscopic inequalities of the revolving journal, and so migrate, filling both surfaces with a fine permanent ingredient of particles non-resistant to change of position. The particles are forced in with great power, by running a heavy journal at moderate speed, or a light one at a swift rate, with the cap screwed tight enough to stop the machinery or twist off the journal if oil instead of metaline were the lubricant. Under such incalculable concentration of force, the particles, instead of being worked out from between the surfaces, are held and incorporated, forming new surfaces of a permanent but peculiar character. Thenceforward, the interaction of these surfaces works infinitesimal movement, or mutual yielding to each other in their numberless infinitesimal particles, which nevertheless retain permanent cohesion by the same law that unites the more fixed particles of the solid metal; a state of movement in stability, foreign to our sensible impression from solids, yet quite as conceivable as the universal molecular motion supposed to constitute heat. A mechanical union of metallic substances seems to be realized, as different in effect as in method—and yet perhaps not so different in principle—from the results of cofusion or amalgamation.

There is nothing in experience to indicate abrasion between these surfaces, except from the gradual breaking off of the high points which the microscope reveals on the surface of the most highly polished journal, projecting above the metaline surface. In the course of years of running on heavy bearings, these points (which so rapidly blacken oil where it is used as the lubricant), become dislodged in such quantity as to cover the surfaces with rigid specks looking like emery under the glass. To prevent this, it is found advisable, once in two or three years, according to circumstances, to replug the bushing or box with metaline (again projecting a hair's breadth) so as replace that which is removed. By this means the bearings improve with use and progressively acquire a higher and higher finish, such, as tested by the microscope, that it is impossible to approximate it by any other method of finishing. Running in oil, on the contrary, wears out journals and misshapes boxes. The longest periods for which journals have as yet been run in metaline—say ten years—have developed no heating or wear, if the bushings have been properly cleaned and replugged once in two or three years. A "shakeless fit" can be secured with metaline, which, as before remarked, would render movement impossible with any mere interposed lubricant. Journals in metalined bearings, under the heaviest weight, or at the highest rate of speed (as in spindles and polishing lathes)